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FILARIASIS IN SOUTHERN UNITED STATES

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By

EDWARD FRANCIS
SURGEON, U. S. PUBLIC HEALTH SERVICE

WASHINGTON
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CONTENTS.

Page.

Introduction 7

Filariasis defined 7

The life cycle of *Filaria bancrofti* 8

Part I. Filarial survey of 10 southern cities:

Charleston, S. C 11

Columbia, S. C 11

Beaufort, S. C 12

Georgetown, S. C 12

Savannah, Ga 13

Milledgeville, Ga 13

Jacksonville, Fla 13

Tampa, Fla 14

Mobile, Ala 15

New Orleans, La 15

The agency of the mosquito in the transmission of filariasis 17

Reasons for the nonspread of filariasis in cities outside of Charleston 18

Why is Charleston an endemic focus of filariasis? 20

Method of examining blood for microfilariæ 20

Staining of microfilariæ 21

Part II. Determination of the mosquito carrier at Charleston:

Infectibility experimentally of *Culex fatigans* with *Filaria bancrofti* 23

Infectibility in nature of *Culex fatigans* with *Filaria bancrofti* 25

"Infected" but not necessarily "infective" 27

Noninfectibility of *Aedes calopus* with *Filaria bancrofti* 28

Different biting habits of *Culex fatigans* and *Aedes calopus* 29

Part III. Prevention of spread of filariasis 31

Part IV. Anatomy of the proboscis in relation to filaria transmission:

The anatomy of the mosquito's proboscis 32

The two courses of filariæ through the proboscis 33

LIST OF ILLUSTRATIONS.

PLATE 1 and 2. Proboscis of mosquito 32

3. *Microfilaria bancrofti* with sheath 35

4. Larvae of *Filaria bancrofti* in thoracic muscles of *Culex fatigans* 35

5. Larva headed into a palpus 35

6. Mature larva escaping from proboscis 35

7. Larva at time of escape from proboscis 35

8. Adult female *Culex fatigans* 35

9. Mosquito cage and sleeve 35

10. Mosquito catcher, and method of mounting mosquitoes on glass slide. 35

FILARIASIS IN SOUTHERN UNITED STATES.

By Edward Francis,
Surgeon, U. S. Public Health Service.

INTRODUCTION.[1]

For the past 30 years filariasis has been known to be endemic at Charleston, S. C., and inasmuch as Charleston's climatic conditions and the species of mosquitoes found there are duplicated in the coast cities of the South, the inference has become general that filariasis is a widespread infection of our southern cities.

The United States Public Health Service, in taking cognizance of the extreme prevalence of filarial infection at Charleston, has conducted a series of investigations having the following objects in view:

(*a*) A filarial survey of a number of southern cities for the purpose of determining, by blood examination, the extent and degree of prevalence of the infection in their population.

(*b*) The determination of the species of mosquito which was acting as the mosquito host and carrier of the infection at Charleston.

(*c*) A determination of the best means of eradicating or preventing the spread of the infection.

FILARIASIS DEFINED.

Filariasis of man is a condition characterized by the presence in the blood of microscopic, slender, snakelike, motile microfilariæ (round worms) which have a length about 30 times the diameter of a red blood corpuscle and a width about equal to the diameter of a red blood cell; they have a rounded head and a tapering tail; they are the offspring of adult female parent worms permanently located in some tissue of the body and discharging their young into the circulation. The parent worms in the case of *Filaria bancrofti* are located in the lymphatics and lymph glands of man; the parent worms of *Filaria loa*, *Filaria perstans*, and *Filaria demarquai* are located in the connective tissue of man. *Filaria bancrofti* is by far the most widespread of the human filariæ and is the species of which this bulletin treats, and for that reason a short general description of that species will now be given, together with some of the symptoms which it causes. *Filaria bancrofti* is found in practically all tropical countries and one endemic focus has been located in the United States—at Charleston, S. C. As the blood of man is the normal habitat of this microfilaria it was at first called *Filaria sanguinis hominis.*

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[1] **Manuscript submitted for publication Nov. 5, 1918.**

A most interesting phenomenon connected with this microfilaria is its night activity and for that reason it has also been called *Filaria nocturna;* the blood of a filarial patient examined during the hours around midnight may show microfilariæ in great numbers, whereas the blood from the same patient examined in the hours around midday may show only one or two parasites. An estimated number of 40 or 50 millions of microfilariæ circulating in the blood may give rise to no symptoms since their size permits them to traverse the capillaries unobstructed. "The healthy, fully formed microfilariæ have, so far as we can tell, no pathogenic properties whatever; the parent worm and the immature products of conception alone are dangerous." (Manson.)

The adult worms may obstruct the thoracic duct or occlude the smaller lymphatic vessels or the lymph glands, resulting in a damming back of the lymph, giving rise to lymph œdema of the undrained area, and due to this increased lymph pressure there results a condition of lymphatic varix or a varicose dilated state of the lymphatic vessels which causes enlargement of the part affected; hence "lymph scrotum," "varicose groin glands" and "varicose axillary glands." If the dilated lymphatic vessels located in the tissues surrounding the kidneys, bladder, testicle or peritoneum become overdistended and rupture, there results a chyluria, chylocele or chylous ascites.

Elephantiasis, although common where *Filaria bancrofti* abounds, is not usually accompanied by microfilariæ in the blood; there are, however, reasons for believing that elephantiasis is a filarial disease in which the female parent worm located in a lymphatic vessel or lymph gland of the effected part has aborted her immature ova, which, on account of having a larger diameter than that of the healthy fully formed microfilariæ cause embolism of the lymphatic glands, resulting in great enlargement or elephantiasis of the leg, arm, breast, scrotum or vulva.

Filariasis is a mosquito-borne disease and several species of mosquito have been found capable of conveying the infection. Some of the known efficient hosts of *Filaria bancrofti* are *Culex fatigans, Stegomyia pseudoscuttelaris*, and *Anopheles maculipennis.*

THE LIFE CYCLE OF FILARIA BANCROFTI.

The adult filariæ are males and females and are found only in the lymphatic system of man. The approximate length of the males is 1½ inches and that of the females is 3½ inches. The number of adult filariæ found in a single individual is small; eight worms would be a large number for one person. Conjugation of the sexes is essential to multiplication and takes place only within the lymphatic system. Multiplication is brought about by the expulsion of embryos by a gravid female. The number of embryos which one female may discharge is very large—probably at least 1,000. The embryos escape from the lymphatic system and circulate in the patient's blood as microfilariæ.

The microfilariæ do not multiply in the blood; any increase in the number of microfilariæ in the blood comes from additional ones thrown into the blood stream from a parent worm located in a lymph gland. The microfilariæ live for a long time in the blood; probably for years. They circulate awaiting the opportunity of being imbibed by a biting mosquito. The mosquito in drawing blood into its stomach draws in also the microfilariæ which after loosing their sheaths in the mosquito's stomach, pierce the stomach wall and pass to the thoracic muscles where they undergo metamorphosis. After a variable time of approximately two weeks spent in the thoracic muscles, the larvæ migrate to the proboscis and there await an opportunity to get back into man, which opportunity presents itself when the mosquito again bites an individual.

During their stay in the mosquito no multiplication of larvæ takes place. The larvæ when they are ready to leave the proboscis measure one-twenty-fifth to one-sixteenth inch in length.

The larvæ on being delivered back to man by the bite of an infected mosquito pass by way of the lymphatics to the nearest lymph gland where they grow to be adult filariæ.

The cycle, as outlined, starts with the parent worm located in a lymphatic gland giving off her microscopic embryos and ends with those embryos developed into 3-inch worms and again located in a lymphatic gland.

I. FILARIAL SURVEY OF TEN SOUTHERN CITIES.

Charleston, S. C.

John Guiteras,[1] in 1886, then a passed assistant surgeon in the United States Public Health Service, stationed at Charleston, S. C., demonstrated microscopically the presence of microfilariæ in the blood of a mulatto woman, a native of Charleston, who had never been outside the city except for five years spent at Augusta, Ga. She had chyluria. He also demonstrated microfilariæ in the blood of a second negro with chyluria; this patient had never been outside of Charleston and its immediate neighborhood.

De Saussure [2] in 1890 reported 22 cases of chyluria with microfilariæ in the blood in people born in Charleston; 9 were colored males, 6 were colored females, 5 were white males and 2 were white females.

Johnson [3] in 1915 reported the blood examination of 400 individuals in the city of Charleston, S. C., representing for the most part consecutive routine admissions to the Roper Hospital; 77 or 19.25 per cent of that number harbored microfilariæ.

Johnson's table showing the groups of individuals examined and the percentage of infection found in each group is here inserted:

	Number examined.	Number infected.	Per cent infected.
White females	50	14	28
White males	50	9	18
Colored females	150	29	19.3
Colored males	150	25	16.7
	400	77	19.25

The writer in 1915 examined the 37 inmates of "The Old Folks' Home," a filarial focus in Charleston, and found that 13, or 35 per cent, of that number showed microfilariæ in their blood.

Columbia, S. C.

Blood examination was made in July, 1918, of 221 unselected individuals in two institutions at Columbia, S. C., and of this number three were found infected.

---

[1] Guiteras, John: The *Filaria sanguinis hominis* in the United States. Medical News, 1886, v. 48, p. 399.

[2] De Saussure, P. G.: A clinical history of 22 cases of *Filaria sanguinis hominis*. Medical News, 1890, v. 56, p. 704.

[3] Johnson, F. B.: Filarial infection. An investigation of its prevalence in Charleston, S. C. Southern Med. J., v. 8, July, 1915, p. 630.

	White.		Colored.	
	Males.	Females.	Males.	Females.
State Hospital for the Insane	50	50	50	50
County poor house	4	5	8	4

Grand total, 221.

Data in regard to the three cases found infected are here inserted.

J. A., colored male, age 33, admitted to State Hospital February 22, 1918. Born in Charleston, 1882, and has always lived in Charleston. Has scars in right groin. Has no glandular enlargement and no elephantiasis. Urine passed was amber in color. Estimated 200 microfilariæ per c. c. of blood.

P. C., colored female, age 22, admitted to State Hospital July 13, 1918. Has always lived in Charleston. Came from Roper Hospital. Has no enlarged glands and no elephantiasis. Urine passed was amber in color. Estimated 20 microfilariæ per c. c. of blood.

J. O. L., white male, age about 40. Admitted to State Hospital July 13, 1918, from Roper Hospital in Charleston. Has spent the past 20 years in Charleston. Has an enlarged gland size of end of thumb in left groin; no other enlarged glands. No elephantiasis. Says that his urine has never been milky or white. Estimated 75 microfilariæ per c. c. of blood.

Beaufort, S. C.

Beaufort is an old coast town of South Carolina, having a population of about 2,500.

The bloods of 67 people were examined April 17 to 20, 1916, for microfilariæ, all of which were negative except one. Five were private cases, 7 were inmates of The Old Folks' Home, 11 were male Negroes in the jail, and 44 were Negro students between the ages of 8 and 20 at the Penn School on St. Helena Island, which lies about 5 miles off the coast of Beaufort.

The following notes were taken on the one positive case found in Beaufort:

D. R., Negro, female, age about 45 years, was born on St. Helena Island; when very young she moved to Beaufort and has never lived elsewhere except for 48 days which she spent in Charleston in 1889. One leg below the knee is larger than the other. Blood examination showed seven microfilariæ on a slide of three large drops. Her mother is about 70 years of age and lived in Charleston from the time she was 10 years of age until she was about 20; examination of the mother's blood was negative for microfilariæ.

Georgetown, S. C.

Georgetown is a very old town of about 5,530 population, located near the coast. The blood examinations of 45 individuals were negative for microfilariæ. Twenty-nine of this number were Negro males in the chain gang, 11 were inmates of the jail, and 5 were private patients.

Dr. Gaillard, who had practiced for 16 years in Georgetown and the county, never saw a case of chyluria, and saw only one case simulating elephantiasis; he examined the blood of the latter several times at night for microfilariæ, but with negative results.

Dr. Sparkman has practiced about 25 years at Georgetown; he said that he had seen only two cases of chyluria, and that both were at Glenn Springs, Spartanburg County, S. C. He said that both were Charlestonians.

I spoke with other physicians who had practiced for a long time in Georgetown—with Drs. Moorer, Sawyer, and Bell—none of whom had seen chyluria or elephantiasis in the town.

Savannah, Ga.

Blood examinations of 287 unselected individuals at Savannah, Ga., were made in 1915 and were found negative. Those examined comprised the patients in the following institutions:

	Males.	Females.
Georgia Infirmary (colored)	75	50
Charity Hospital (colored)	50	50
St. Joseph's Hospital (white)	5	
United States Marine Hospital (only colored patients examined)	13	
Abrams' Home for the Aged (white)		44
Total	143	144

Dr. V. H. Bassett, bacteriologist for the past eight years of the city department of health, Savannah, Ga., informed me that only one case had come to his notice in Savannah in which microfilariæ had been demonstrated in the blood; this case was a native of the West Indies.

Milledgeville, Ga.

Blood examinations of 100 inmates of the State Insane Asylum, Milledgeville, Ga., were made in 1915 and all were found negative; this number embraced 45 white females and 55 colored females. The patients of the institution are drawn from all parts of the State, so that, to a limited extent, the examinations afford an index of conditions in many localities.

Jacksonville, Fla.

Blood examination was made May 22 and 23, 1916, of 200 individuals in the following institutions:

Duval County Hospital (mixed)	66
St. Luke's Hospital (white)	20
Brewster Hospital (colored)	14
City prison farm (mixed)	100
Total	200

All were found negative except two colored males; these were met with at the city prison farm and both were natives of Charleston, S. C. A brief summary of these two cases is here given:

No. 113. Negro, male; age, 23; born in Charleston, S. C.; left Charleston at age of 16 years for Fernandina, Fla., and thénce to Jacksonville; shows no evidence of filariasis other than the blood findings; estimated 40 microfilariæ per c. c. of blood.

No. 140. Negro, male: age, 23; born in Charleston, S. C.; lived in Charleston until 18 years of age; came to Jacksonville two or three years ago; presents no evidence of filarial infection except the blood findings; estimated 360 microfilariæ per c. c. of blood.

While in Jacksonville I was told by Dr. H. Hanson, director of the laboratory of the State Board of Health at Jacksonville, that 20,000 blood smears had been examined for malaria in that laboratory coming from all over Florida, and that no microfilariæ had been found in them; malarial smears are usually taken in the daytime, however. He also said that not a single case of chyluria had come to their notice in five years in routine examination of urine in the laboratory at Jacksonville. In this connection the late Surg. R. H. von Ezdorf, United States Public Health Service, told me that in 13,500 thick blood smears taken in various Southern States and stained and examined for malaria no microfilariæ had been found.

Tampa, Fla.

Blood examination was made May 11 to 16, 1916, of 115 individuals at Tampa, Fla., in the following institutions:

	Males.	Females.
Hillsborough County Farm and Hospital (mixed)	64	15
County jail (colored)	31	
Private	3	2

Grand total, 115.

All examinations were negative for microfilariæ, except the following three:

No. 73 (private case). Spaniard, male; has spent many years in Tampa and Cuba. Microfilariæ were found on blood examination; this condition had, however, been diagnosed in 1911. Says he has intermittent chyluria.

No. 13. Spaniard, male; has spent the past 10 years in Tampa, while for 40 year previously he had lived in Habana. Says he has had chyluria. Microfilariæ in blood

No. 21. German, male, born in Germany; came to New York during the Civil Wa and came to Tampa when the city was a "mere village;" spent six months in Charleston in 1868, and spent seven months in Charleston again some time later; he has neve been in Cuba. Has an enlarged testicle. Microfilariæ were found on blood examination.

Examination of the annual reports of the Florida State Board c Health since 1907 showed only two cases in which the blood examir tions had been positive. Both were reported by Dr. G. W. Simon, charge of the State bacteriological laboratory at Tampa; one of these cases was reported in 1911 and probably was my case No. 73 above, while the other was reported in 1912 as simply positive for *Filaria bancrofti*, without any further details.

Mobile, Ala.

In Mobile, in July, 1918, blood examination of 131 unselected individuals distributed among the following institutions was negative:

	White.		Colored.	
	Males.	Females.	Males.	Females.
United States Marine Hospital	18		7	
City hospital	8	9	16	9
County poorhouse	17	21	16	10

Grand total, 131.

In addition, five private selected cases were examined for microfilariæ in the blood and found negative; two of these were white females with elephantiasis involving one leg below the knee; one was a white female who had had chyluria one year previously; one was a white male in whose blood microfilariæ were said to have been found in 1908 and who said that he had had attacks of chyluria; the other was said to have had chyluria.

New Orleans, La.

Blood examinations were made for microfilariæ in New Orleans in June, 1918, of 304 unselected individuals in the following institutions, all with negative results:

Institution.	White.		Colored.	
	Male.	Female.	Male.	Female.
Lafon Home, 1125 North Tonti Street			12	52
Faith Home, 3017 Bernadotte Street				11
Freedman's Home, Audobon Street			2	9
Lafon Home, South Robertson Street			4	12
German Protestant Home	21	23		
Touro Shakespeare Home	74	34		
Charity Hospital			50	
	95	57	68	84

Grand total, 304.

I was told while in New Orleans by Dr. C. C. Bass and by Dr. Wm. H. Harris that they had never seen microfilariæ in the fresh blood of the human subject in New Orleans, although special examinations had been made of those most likely to harbor the parasites, such as West Indians and Porto Ricans, and natives of New Orleans, including those who show an elephantiasis of the type on which Dr. Rudolph Matas[1] has written.

Table showing summary of surveys of 10 Southern cities for Microfilaria bancrofti.

Number of individuals examined.	Number of individuals found infected.	Estimated number of microfilariæ per c. c. of blood.
Charleston, S. C.: 400[1]	77	....
Columbia, S. C.: 221	3	200, 20, 75
Beaufort, S. C.: 67	1	21
Georgetown, S. C.: 45	....	....
Savannah, Ga.: 287	....	....
Milledgeville, Ga.: 160	....	....
Jacksonville, Fla.: 200	2	40, 360
Tampa, Fla.: 115	3	160, 130, 110
Mobile, Ala.: 131	....	....
New Orleans, La.: 304	....	....

[1] The figures given for Charleston are taken from Johnson's report because they comprise a very large number of individuals examined; the figures for the nine cities outside of Charleston are from my surveys.

An examination of the above table shows that of 400 individuals examined at Charleston, S. C., 77 were found to be infected with microfilariæ, whereas of 1,470 individuals examined in nine southern cities outside of Charleston only 9 individuals were found to harbor microfilariæ in their blood. A study of the table points to Charleston as a heavy focus of infection and indicates that Georgetown, S. C., Savannah, Ga., Milledgeville, Ga., Mobile and New Orleans are free from infection. The table also indicates that Columbia, S. C., Beaufort, S. C., Jacksonville, Fla., and Tampa, Fla., contain small foci of infection, inasmuch as 9 cases were found out of 603 individuals examined in those four cities. But the very interesting fact developed that these 9 cases found in Columbia, Beaufort, Jacksonville, and Tampa give histories either of having been born and raised in Charleston or of having spent a considerable period of time in Charleston or of having been born in Cuba which is a well-known filarial focus.

The data point to Charleston as the one active endemic focus of the disease in the South and indicate that cases found outside of Charleston have derived their infection either from residence in Charleston or from residence at some place outside of the United States, as in Cuba. The data indicate that the isolated cases found outside of Charleston do not constitute a new focus for transmission of the disease to people with whom they come in contact in their new locality. At first thought it is surprising that each case transplanted from Charleston to another city does not become a focus for the spread of the infection. This is accounted for on the grounds of the great difficulties which attend the mosquito transmission of the disease. Yellow fever, malaria, and filariasis are mosquito-borne diseases, and we know that both yellow fever and malaria do spread from one community to another in the South, but it has not been shown that filariasis has yet produced an endemic focus in a southern city outside of Charleston, although Charleston has been known to be an endemic focus of filariasis for the past 30 years and infected individuals have moved from Charleston to other cities and natives of other cities have returned home after spending considerable time in Charleston.

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[1] Matas, Rudolph: The surgical treatment of elephantiasis and elephantoid states dependent upon chronic obstruction of the lymphatic and venous channels. Am. J. Trop. Dis. & Prev. Med., v. 1 (1), July, 1913, p. 60, etc.

THE AGENCY OF THE MOSQUITO IN THE TRANSMISSION OF FILARIASIS.

We recognize the mosquito as the sole agent in the transmission of filariasis just as we recognize the mosquito as the sole agent in the transmission of yellow fever and malaria, but mosquito transmission is accomplished with much less degree of certainty and promptness in filariasis than in yellow fever and malaria, owing to certain marked essential differences in the process of mosquito transmission in the three diseases.

The *first* difference is that while in the case of malaria, and probably in yellow fever also, the parasite multiplies enormously in the mosquito, no multiplication of the filarial parasite whatever takes place in the mosquito; if the mosquito imbibes only one microfilaria from the blood of a filarial patient she can give back only one larva to the human subject.

The *second* difference in the process is that in filariasis every act or step of mosquito transmission is characterized by a small number of parasites; the number of microfilariæ imbibed by the mosquito is small and the number which successfully pass through the larval stage in her thoracic muscles and finally reach the proboscis to await the opportunity of an infecting bite is remarkably small; and the number of adults which reach a lymphatic gland of man is smaller still.

The *third* difference is that the filarial parasite as it leaves the mosquito's proboscis for man is of one sex or the other, and that multiplication must be deferred until a male and a female find lodgment within the *same* lymph gland of man and there grow and develop their genital organs preparatory to bringing about a fecundated adult female parent worm permanently located in that lymph gland and discharging her embryos into the blood stream. It is entirely possible that an individual might harbor a considerable number of adult parasites in his lymph glands and yet show no microfilariæ in his blood for the reason that those adults were so distributed among a number of lymph glands as to separate the sexes and thus preclude conjugation.

The *fourth* difference is found in the limited number of hours of maximum opportunity of infecting mosquitoes with filariæ; those hours being restricted to a few before midnight and a few after midnight.

The *fifth* difference in the process is that in the biting act which delivers the filarial larva back to man, the mosquito does not inject the larva into the blood stream of man but drops the larva on the free surface of the skin. The larva must then penetrate the intact skin and pass by the lymphatics to the nearest lymph gland.

Sixth. There are, moreover, certain additional difficulties attending the mosquito transmission of filariasis which weaken its efficiency. Probably half of the microfilariæ taken into a mosquito's stomach pass on into the hind gut and are lost instead of piercing the stomach wall and lodging in the thoracic muscles where the necessary larval changes must take place. Certainly a large proportion of the larvæ after they leave the thoracic muscles migrate backward into the abdomen and are lost, while others migrate into the legs or into the antennæ and palpi instead of into their necessary infecting position in the proboscis. The larvæ after liberation upon the skin are subject to being wiped off or washed off before they can penetrate the skin. The life of an infected mosquito is probably shortened by reason of harboring the worms.

REASONS FOR THE NONSPREAD OF FILARIASIS IN CITIES OUTSIDE OF CHARLESTON.

The nonspread of filariasis in cities to which infected Charlestonians have been transported is accounted for by the absence of mass blood infection in those transported cases and the absence of mass mosquito biting of those cases in their new localities.

Large numbers constitute an essential factor in the process of mosquito transmission of filariasis and malaria. In malaria the large number characterizes the parasites in the mosquito and in man and is brought about by multiplication; but in filariasis the number of parasites in the mosquito and in man is small, so that the large number essential to successful transmission must be found in the mosquitoes themselves—in mass mosquito biting. There is also an absence of large numbers of microfilariæ in the blood of cases of filariasis found outside of Charleston—an absence of mass blood infection. It is the combination of small blood infection and small mosquito biting that accounts for the nonspread of filariasis *in cities,* outside of Charleston. In the absence of mass blood infection and of mass mosquito biting, the transmission of filariasis is a rare accidental affair.

Microfilariæ are so large and their number is so small that they admit of being counted and therefore I will attempt to show by calculation the necessity of the two factors of mass blood infection and mass mosquito biting in bringing about a spread of the infection.

The nine cases of filariasis found in cities outside of Charleston (see table, page 16) showed an estimated average of only 124 microfilariæ per c. c. of blood. Supposing that an infected individual harbors 124 microfilariæ per c. c. of his blood and that a mosquito draws 1.15 milligrams (0.00115 c. c.) of blood at a bite, a mosquito would then have to bite such an infected individual seven times in order to get one microfilaria or if seven mosquitoes bit him, only one of the seven would imbibe a microfilaria. If this one microfilaria encountered no obstacles whatever in its cycle either in the mosquito's stomach, in the thoracic muscles of the mosquito or in its proboscis or on the human skin or in the lymphatics of man, it would successfully reach a lymph gland. Here its activities would, however, come to an end by reason of being a male or a female and by reason of the absence of one of the opposite sex.

The calculation goes to show the failure to convey filariasis of seven bites of mosquitoes which have fed upon a filarial patient whose blood content of microfilariæ is 124 per c. c.

A second set of 7 mosquito bites, if successful, might result in the deposit of a second filaria in some lymph gland of the body but quite distant from the first one. Mosquitoes have a wide choice of skin surface over which to distribute their bites and consequently there is a wide choice of lymph glands in which the infecting worm may lodge. It would not be difficult to distribute 10 infective mosquito bites over the body surface in such locations that no two of the ten implanted filariæ would meet in the same gland.

An individual harboring 10 adult filariæ implanted in 10 different lymph glands of his body and representing the bites of 70 mosquitoes which had bitten a patient harboring 124 microfilariæ per c. c. of blood, might not have a single microfilaria in his blood on account of the complete separation of the 10 adult males and females.

And even if a male and female should successfully lodge in the same lymph gland and if the female discharged 1,000 embryos into the blood stream and if the volume of the patient's blood was 6,000 c. c., the distribution of microfilariæ in the blood would be only one per 6 c. c. of blood; and if a *Culex fatigans* draws 1.15 milligrams of blood at a bite it would require 5,217 mosquito bites before a mosquito would succeed in imbibing one microfilaria.

WHY IS CHARLESTON AN ENDEMIC FOCUS OF FILARIASIS?

The questions as to when and from what place did Charleston derive her infection probably find their answer in that a shipload of slaves from a heavy focus of infection in Africa was landed in the city many year ago.

The answer to the question as to why the disease became endemic at that place is that the conditions of filarial transmission (mass blood infection and mass mosquito biting) found their fulfillment in the peculiarity of the condition that the infected individuals, being slaves, were held compactly together at that place freely exposed to mosquitoes.

The question as to why Charleston continues to remain an endemic focus of filariasis finds its answer in the fact of the continued presence in Charleston of a large number of cases of filariasis showing a high blood content of microfilariæ and exposed to constant biting by *Culex fàtigans.*

These explanations are based upon the peculiarity of the process of mosquito transmission of filariasis that large numbers are essential. The various acts concerned in the process of mosquito transmission must be repeated in great numbers because of the small number of parasites concerned in each act of the process.

In order to bring about the transmission of filarial infection from one person to another, the infecting individual must harbor a large number of microfilariæ in his blood; he must be bitten by a large number of mosquitoes in order that some of those mosquitoes may become infected and a large number of infected mosquitoes must bite the individual who is to become infected.

METHOD OF EXAMINING BLOOD FOR MICROFILARIÆ.

In the method of examination employed, blood was collected between 10.30 p. m. and 1.30 a. m. by sticking, with a Hagedorn needle, the tip of the finger from which 6 to 8 large drops (¼ to ⅓ c. c.) of blood were squeezed out and allowed to fall on an ordinary clean glass slide. With a fresh toothpick the blood is evenly spread, before clotting, over the entire surface of the slide excepting a small area at one end reserved for a number scratched in with a diamond writing pencil. The thick blood films are dried in the air in a level position, protected from roaches and flies but freely exposed to the air. As soon as dry, the slides are stood upright, back to back, in Coplin jars containing preferably distilled water, or containing good tap water. The film should be dehemoglobinized as soon as dry in order to get a colorless film. An hour usually suffices for the water to entirely remove the hemoglobin from the red corpuscles, leaving the film colorless but otherwise unaltered. If desirable, the slides can be transferred to fresh water to complete the laking. As soon as laking of the hemoglobin is complete, the slides are examined while still wet on a mechanical stage under a 16-millimeter objective; in such preparations the glistening microfilariæ are readily distinguished. In routine work where a determination of the number of individuals infected is the sole object of the investigation, examination of the wet laked films is entirely satisfactory and was followed in our surveys.

It became necessary in some instances for the films to remain wet 48 hours while awaiting their turn for examination. In such cases, bacterial growth is likely to disintegrate the film and cause its detachment from the slide; a few drops of formalin added to the water will prevent such results.

STAINING OF MICROFILARIÆ.

Thick smears decolorized in distilled water as described above are sufficiently fixed to the slide by drying in the air.

Stain with Delafield's hemotoxylin for five minutes, steaming the stain over a flame as in staining tubercle bacilli. Wash thoroughly in tap water. Examination with the two-thirds objective shows that the preparation is overstained. Therefore, decolorize with acid alcohol sufficiently to differentiate with the low power the cells of the cell column of the parasite. Dehydrate in absolute alcohol, clear in oil of cloves or xylol, mount in Canada balsam. Staining of the parasites becomes necessary when it is desired to study their structure.

The polychrome stains commonly employed in blood examinations may also be used.

II. DETERMINATION OF THE MOSQUITO CARRIER AT CHARLESTON.

Conclusion as to which species of mosquito was acting as the mosquito host at Charleston was reached after making a mosquito survey in a heavily infected focus of filarial infection in Charleston (The Old Folks' Home) and after experimental demonstration of the infection in a certain species of mosquito found very prevalent in that focus.

A mosquito survey was made covering the determination of 1,000 mosquitoes collected at "The Old Folks' Home" in Charleston.

Experimental demonstration of the infection in the mosquito was derived by dissection of mosquitoes caught at the "Home" in bedrooms occupied by filarial patients and by dissection of mosquitoes which it had been attempted to infect experimentally in cages by allowing them to bite persons at the "Home" in whose blood microfilariæ were circulating.

A determination of 1,000 adult mosquitoes captured in rooms of "The Old Folks' Home" was made by the writer who classified them as follows:

Culex fatigans	902
Aedes calopus	91
Aedes solicitans	5
Anopheles quadrimaculatus	2
	1,000

In as much as the survey showed the prevalence of *Culex fatigans* and *Ædes calopus* almost to the exclusion of all other species, these two were selected for examination by dissection for evidence of filarial infection.

Culex fatigans and *Ædes calopus* represent by far the commonest house mosquitoes of the Southern States, and while these two species are constantly associated in that section, breeding together in house yards in the same water and in the same containers, *Ædes calopus* has never been proven an efficient host of *Filaria bancrofti.*

Culex fatigans, on the other hand, has long been proven a transmitter of *Filaria bancrofti,* and therefore it was to be expected that this species of mosquito would be bound to be the intermediary host at Charleston.

Determination as to whether a mosquito was infected with filariæ was reached by dissection of the mosquito and examination under the microscope of its thorax, abdomen, head, and proboscis for the presence of the developmental stages through which filariæ pass in the course of their migration through the organs of the mosquito host.

The mosquito dissections resulted in the finding of a high percentage of *Culex fatigans* infected with filariæ and the finding of all

Ædes calopus negative for that infection, thus showing conclusively that *Culex fatigans* is a transmitter of *Filaria bancrofti* at Charleston and that its constant associate, *Ædes calopus*, is incapable of such transmission.

INFECTIBILITY EXPERIMENTALLY OF CULEX FATIGANS WITH FILARIA BANCROTI.

Detailed data bearing upon the infectibility experimentally of *Culex fatigans* is found by reference to Tables Nos. 1 and 2.

Table No. 1 gives the data upon 27 *Culex fatigans* raised from larvæ in a noninfected community (Savannah, Ga.) and fed in cages at Charleston, S. C., upon patients heavily infected with *Filaria bancrofti;* 20 of the 27 mosquitoes so fed, or 74 per cent, contained larval forms of *Filaria bancrofti* at the time of dissection.

TABLE No. 1.—*Showing infectibility experimentally of Culex fatigans raised from larvæ in Savannah, Ga., and fed in cages at Charleston, S. C., upon blood of patients infected with Filaria bancrofti; 27 mosquitoes so fed were dissected at intervals, as shown below, 20 of which, or 74 per cent, contained larval forms of Filaria bancrofti.*

Dates of feeding of mosquitoes in cages upon filarial patients.	Dates of dissection of mosquitoes for filariæ.	Number of larvæ found in thorax on dissection.	Number of larvæ found in head and proboscis on dissection.	Number of larvæ found in abdomen on dissection.
Sept. 9, 10, 11, 13, 14, and 15, 1915. (See Table No. 5, column 1.)	Sept. 17, 1 dead	7 young larvæ	None	None.
	Sept. 17, 2 dead	None	None.	None.
	Sept. 18, 1 dead	5 young larvæ	None	None.
	do	2 young larvæ	None	None.
	do	20 young larvæ	None	None.
	do	1 young larva	None	None.
	do	do		
	do	7 young larvæ		
	do	6 young larvæ		
	Sept. 18, 2 dead	None		
	Sept. 19, 1 dead	12 young larvæ		
	do	2 young larvæ		
	Sept. 19, 3 killed	None	None	None.
	Sept. 23, 1 dead	36 young larvæ; 1 half-grown; measured, stained, 0.47 by 0.027 mm.		None.
	Sept. 28, 1 dead	6 young larvæ, 1 mature larva.	None	1 mature larva measured fresh 1.175 by 0.022 mm.
	Sept. 30, 1 dead	1 young larva. 1 mature larva.		
	Oct. 3, 1 died	None	Head contained 3 mature larvæ; 1 measured fresh 1.48 by 0.025 mm. Proboscis contained 1 mature larva.	
	Oct. 11, 1 dead	None	Head contained 1 mature larva.	None.
	Oct. 12, 1 dead	1 entire mature larva	None	None.
	Oct. 12, 1 killed	Anterior and posterior ends of a mature larva seen.	1 motile mature larva seen in proboscis.	An anterior end of a mature larva seen.
	Oct. 18, 1 killed	1 larva measured fresh 0.68 by 0.020 mm. An anterior and a posterior end of a mature larva seen.	None	None.
	do	1 larva measured fresh 0.98 by 0.029 mm.	None	None.
	do	1 mature larva measured fresh 1.52 mm. in length.	1 mature larva	None.

Table No. 2 shows the infectibility experimentally of *Culex fatigans* caught at "The Old Folks' Home" in rooms occupied by nonfilarial patients but infected in cages by being allowed to feed upon the hands of filarial patients; 52 mosquitoes so fed were dissected for evidence of filarial infection, 34 of which, or 65 per cent, were found to be infected with filariæ.

TABLE No. 2.—*Showing infectibility experimentally of Culex fatigans caught at "The Old Folks' Home," Charleston, S. C., in rooms occupied by nonfilarial patients and allowed to feed in cages upon the hands of patients infected with Filaria bancrofti; 52 mosquitoes so fed were dissected, as shown below, 34 of which, or 65 per cent, were found to be infected with filariæ.*

Dates of feeding of mosquitoes in cages upon filarial patients.	Date of dissection of mosquito for filariæ.	Number of larvæ found in thorax of mosquito on dissection.	Number of larvæ found in head and proboscis of mosquito on dissection.	Number of larvæ found in abdomen of mosquito on dissection.
Sept. 16, 17, 18, 19, 20, and 21, 1915. (See Table No. 5, column 3.)	Sept. 18, 2 dead	None	None	None.
	Sept. 19, 1 dead	1 young larva		None.
	do	None	None	None.
	Sept. 20, 1 killed 9 hours after feeding.	1 microfilaria		None in stained blood.
	Sept. 21, 1 killed 9 hours after feeding.	6 microfilariæ, stained.		4 microfilariæ in stained blood.
	Sept. 23, 1 killed 36 hours after feeding.	1 microfilaria, stained		1 microfilaria, stained.
	Sept. 25, 1 killed 60 hours after feeding.	do	None	Do.
	Sept. 26, 1 died	1 mature larva, stained; 12 young larvæ.	None	None.
	Sept. 27, 1 died	2 young larvæ	None	None.
	Sept. 28, 1 dead	Several young larvæ.	None	None.
	do	2 young larvæ	None	None.
	Oct. 3, 1 dead	2 anterior ends of mature larvæ.	None	None.
	do	1 anterior end of mature larva.	None	None.
	Oct. 3, 2 dead	None	None	None.
	Oct. 4, 1 dead	22 young larvæ	None	
	Oct. 5, 1 dead	2 mature larvæ	1 mature larva in head.	2 mature larvæ.
	do	do		
	do	Piece of mature larva	2 mature larvæ in proboscis, stained.	Piece of mature larva.
	Oct. 7, 1 killed	None	None	None.
	Oct. 8, 1 killed	Pieces of mature larva.	None	None.
	do			Pieces of mature larva.
	do		1 mature larva in proboscis measured fresh 1.54 by 0.028 mm. 1 mature larva in head.	
	Oct. 8, 2 killed	None	None	None.
	Oct. 9, 1 dead		1 mature larva in proboscis. 1 mature larva in antenna.	Anterior portion of mature larva.
	Oct. 10, 1 dead	2 mature larvæ		
	Oct. 11, 1 dead	None	Posterior end of mature larva.	None.
	do	None	1 mature larva, measured fresh 1.44 by 0.025 mm.	
	do	None	1 mature larva	None.
	do	None	None	None.
	Oct. 12, 1 dead	Anterior end of mature larva.	None	Anterior end of mature larva.

TABLE No. 2.—*Showing infectibility experimentally of Culex fatigans caught at "The Old Folks' Home," Charleston, S. C., in rooms occupied by nonfilarial patients and allowed to feed in cages upon the hands of patients infected with Filaria bancrofti; 52 mosquitoes so fed were dissected, as shown below, 34 of which, or 65 per cent, were found o be infected with filariæ*—Continued.

Dates of feeding of mosquitoes in cages upon filarial patients.	Date of dissection of mosquito for filariæ.	Number of larvæ found in thorax of mosquito on dissection.	Number of larvæ found in head and proboscis of mosquito on dissection.	Number of larvæ found in abdomen of mosquito on dissection.
Sept. 16, 17, 18, 19, 20, and 21, 1915, (See Table No. 5, column 3.)	Oct. 12, 1 dead	None	1 mature larva in an antenna, measured fresh 1.30 by 0.025 mm.	
	do	None	None	Piece of mature larva.
	Oct. 14, 1 killed		1 mature larva in proboscis. 1 mature larva in head.	
	do	None	None	Anterior end of mature larva.
	Oct. 14, 2 killed	None	None	None.
	Oct. 15, 1 killed	None	Anterior portion of larva in palpus.	Anterior and posterior ends of mature larva.
	do	None	1 mature larva in head.	
	do	Half-grown larva, measured fresh 0.76 by 0.033 mm.	None	1 mature larva.
	Oct. 15, 3 killed	None	None	None.
	Oct. 16, 1 killed	Piece of mature larva	None	None.
	do	None	2 mature larvæ in head, measured fresh 1.59 by 0.027 mm. and 1.45 by 0.027 mm.	None.
	Oct. 16, 1 dead	None	None	None.
	Oct. 18, 1 dead	Posterior end of mature larva.	1 mature larva in an antenna.	None.
	Oct. 19, 3 killed	None	None	None.

NOTE.—The possibility exists that some of the mosquitoes found infected in the above experiment derived their infection in nature before confinement to cages; i. e., that they were already infected before being allowed to feed in cages upon the hands of infected patients. This possibility arises from the fact of their having been caught in a filarial focus, "The Old Folks' Home," but in rooms occupied by nonfilarial patients. The percentage which may have thus derived their infection in nature can be estimated from a control series of dissections which was made of 100 *Culex fatigans* caught at "The Old Folks' Home" in rooms occupied by nonfilarial patients; 5 of that number or 5 per cent were found infected.

INFECTIBILITY IN NATURE OF CULEX FATIGANS WITH FILARIA BANCROFTI.

Detailed data bearing upon the infectibility in nature of *Culex fatigans* with *Filaria bancrofti* is found in Table No. 3. This table shows that of 65 *Culex fatigans* caught at "The Old Folks' Home" on the walls of rooms occupied by filarial patients, 13, or 20 per cent, were found on dissection to contain larval filariæ.

TABLE No. 3.—*Showing infectibility, in nature, of Culex fatigans with Filaria bancrofti. Sixty-five Culex fatigans were caught Sept. 24 and Sept. 25, 1915, in Charleston at "The Old Folks' Home" on the walls of rooms occupied by filarial patients. These were dissected, as shown below, 13 of which, or 20 per cent, were found to contain larval filariæ.*

Dates of dissection of mosquitoes for filariæ.	Number of larvæ found in thorax of mosquito.	Number of larvæ found in head and proboscis of mosquito.	Number of larvæ found in abdomen of mosquito.
Sept. 26, 1 dead	1 young larva		
Sept. 26, 3 dead	None		
Sept. 27, 7 dead	None		
Sept. 28, 1 dead	2 larvæ, stained, length 0.87 mm. and 1.0 mm. 3 young larvæ.		
Sept. 28, 3 dead	None		
Sept. 29, 1 dead	1 young larva	None	Anterior end of mature larva.
Do	do	None	None.
Sept. 29, 6 dead	None	None	None.
Sept. 30, 1 dead	2 young larvæ, 1 half-grown larva.	1 mature larva seen emerging from end of proboscis.	None.
Do	1 crumpled larva	None	None.
Do	4 young larvæ	None	
Do		Proboscis contained 2 mature larvæ.	
Sept. 30, 5 dead	None	None	None.
Oct. 1, 1 dead	1 mature larva, 1 young larva.	None	None.
Do	24 young larvæ	None	None.
Do	1 mature larva, stained	None	
Oct. 1, 3 dead	None	None	None.
Oct. 2, 3 dead	None	None	None.
Oct. 3, 1 dead	2 young larvæ	None	None.
Oct. 3, 2 dead	None	None	None.
Oct. 5, 3 dead	None	None	None.
Oct. 6, 3 dead	None	None	None.
Oct. 7, 3 dead	None	None	None.
Oct. 8, 8 killed	None	None	None.
Oct. 12, 1 dead	None	1 mature larva in proboscis.	None.
Oct. 12, 3 dead	None	None	None.

NOTE.—Fifty *Aedes calopus* were caught Sept. 24 and 25, 1915, in Charleston at "The Old Folks' Home" on the walls of rooms occupied by filarial patients. All were dissected in saline solution, none of which contained larval filariæ, as shown below:

Dates of dissection of 50 Aedes calopus for filariæ.	Number of larvæ found in thorax of mosquito.	Number of larvæ found in head and proboscis of mosquito.	Number of larvæ found in abdomen of mosquito.
Sept. 29, 1 dead	None	None	None.
Sept. 30, 5 dead	None	None	None.
Oct. 1, 9 dead	None	None	None.
Oct. 2, 1 dead	None	None	None.
Oct. 4, 1 dead	None	None	None.
Oct. 5, 1 dead	None	None	None.
Oct. 6, 1 dead	None	None	None.
Oct. 7, 1 dead	None	None	None.
Oct. 8, 8 killed	None	None	None.
Oct. 9, 8 killed	None	None	None.
Oct. 12, 8 killed	None	None	None.
Oct. 23, 6 killed	None	None	None.

"INFECTED" BUT NOT NECESSARILY INFECTIVE."

Tables 1, 2, and 3 have given the numbers of *Culex fatigans* which on dissection were found to be infected with *Filaria bancrofti;* the term "infected" is taken to include all mosquitoes which harbored developmental forms of filaria in any part of their bodies (in head, thorax, proboscis, antenna, palpus, or abdomen).

It is evident that the bite of an "infected" mosquito may not be "infective" at all.

The bite of an infected mosquito is infective for man only at the time that that mosquito harbors mature larvæ actually in its proboscis; adult larvæ located in the mosquito's abdomen, thorax, head, legs, antennæ, or palpi can not, while so located, render infective their host's bite.

Table No. 4 summarizes the locations in the bodies of 67 infected *Culex fatigans* in which mature larvæ, young larvæ, and microfilariæ were found on dissection.

Table No. 4.—*Summary of Tables 1, 2, and 3, showing the total number of microfilariæ, young larvæ, and adult larvæ, with their seats of distribution in the different parts of the bodies of 67 infected Culex fatigans, found on dissection.*

Part of the mosquito's body in which filariæ were found on dissection.	20 infected *Culex fatigans.* (See Table 1.) 34 infected *Culex fatigans.* (See Table 2.) 13 infected *Culex fatigans.* (See Table 3.) — 67		
	Number of mature larvæ found.	Number of young larvæ found.	Number of microfilariæ found.
Proboscis	11		
Antenna	3		
Palpus	1		
Head	14		
Thorax	26	195	9
Abdomen	13		6
Total mature larvæ	68		

Table No. 4 shows that 67 infected mosquitoes contained on dissection only 68 mature larvæ and of this number of larvæ only 11 were located in the proboscis, i. e., only 11 were at the time ot dissection so located as to render infective the bites of the 9 mosquitoes which harbored them. At the time of dissection, 13 mature larvæ were located in the abdomens of 12 mosquitoes and were, of course, entirely outside the possibility of rendering infective their host's bite. Three mature larvæ were headed into antennæ and 1 into a palpus. Fourteen mature larvæ were located in the mosquito's head and probably would reach the proboscis. Twenty-six mature larvæ were still in the thorax, with about equal chances of migrating either forward toward the proboscis or backward into the abdomen.

NONINFECTIBILITY OF ÆDES CALOPUS WITH FILARIA BANCROFTI.

Ædes calopus has never been proven an efficient host of *Filaria bancrofti*. *Microfilariæ bancrofti* taken into this mosquito's stomach do pierce the stomach wall in limited numbers and lodge in the thoracic muscles, but there they die as microfilariæ without development into the larval stage.

While our experimental studies of the infectibility of *Culex fatigans* were being made, it was thought advisable also to carry on a parallel set of experiments to test the infectibility of *Ædes calopus* with the species of filaria prevailing at Charleston, inasmuch as no experimental study has been reported having for its object the determination of the mosquito carrier of filariasis in the United States.

All experiments made and reported in Tables 1 and 3 to prove the infectibility of *Culex fatigans* were accompanied by an exactly parallel series of experiments to test the infectibility of *Ædes calopus*.

One hundred and twenty-four *Ædes calopus* (see Table 5, column 2) exposed to infection with *Filaria bancrofti* under exactly the same conditions as were 20 *Culex fatigans* found infected in Table 1, were all found negative for that infection on dissection. These 124 *Ædes calopus* were raised from larvæ in Savannah and were fed in cages in Charleston, between September 9 and 16, 1915, upon the blood of filarial patients, and were thereafter kept at a temperature of 26° C. and fed on simple sirup. They were dissected at times between September 19 and October 23 for evidence of filarial infection, but gave entirely negative results except for the first 6 which showed in the thoracic muscles from 1 to 4 unsheathed microfilariæ. (See Table No. 5, column 2.)

Fifty *Ædes calopus* (see Table No. 3, note), exposed to infection with *Filaria bancrofti* under exactly the same conditions as were 13 *Culex fatigans* found infected in Table No. 3, were all found negative for that infection on dissection. These 50 *Ædes calopus* were caught September 24 and 25, 1915, in Charleston at "The Old Folks' Home" on the walls of rooms occupied by filarial patients and were thereafter kept at a temperature of 26° C. and fed on simple sirup. They were dissected at times between September 29 and October 23 without finding in them any filariæ whatever. (See Table No. 3 note.)

TABLE No. 5.—*Showing method of feeding by which Culex fatigans was experimentally infected and Ædes calopus failed of infection with Filaria bancrofti at Charleston, S. C.*

<table>
<tr><th>Filarial patients.</th><th>Number of microfilariæ per c. c. of patient's blood examined at midnight.</th><th>Number of microfilariæ per c. c. of patient's blood examined at noon.</th><th>1915</th><th>Column 1.
400 <i>Culex fatigans</i>, raised from larvæ in Savannah, were placed, 100 in each of cages 1, 2, 3, and 4, into which filarial patients in Charleston introduced their hands, as indicated below.</th><th>Column 2.
400 <i>Ædes calopus</i>, raised from larvæ in Savannah, were placed, 100 in each of cages 1, 2, 3, and 4, into which filarial patients in Charleston introduced their hands, as indicated below.</th></tr>
<tr><td>Case 1.......</td><td>460</td><td>0</td><td>Sept. 9</td><td>Case 1 fed cages 2 and 3.</td><td>Cage 1 fed cage 4.
Case 2 fed cage 1.
Case 3 fed cages 2 and 3.</td></tr>
<tr><td>Case 2.......</td><td>2,000</td><td>21</td><td></td><td></td><td></td></tr>
<tr><td>Case 3.......</td><td>3,000</td><td>14</td><td></td><td></td><td></td></tr>
<tr><td>Case 4.......</td><td>2,465</td><td>26</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td>Sept. 10</td><td>Case 2 fed cage 1.
Case 3 fed cage 4.</td><td>Case 2 fed cage 2.
Case 3 fed cage 1.
Case 1 fed cage 3.</td></tr>
<tr><td></td><td></td><td></td><td>Sept. 11</td><td>Case 1 fed cage 2.
Case 2 fed cage 3.
Case 3 fed cage 1.</td><td>Case 1 fed cages 1 and 2.
Case 2 fed cage 4.
Case 3 fed cage 3.</td></tr>
<tr><td></td><td></td><td></td><td>Sept. 13</td><td>Case 2 fed cage 4.
Case 3 fed cage 3.</td><td>Case 2 fed cage 3.
Case 3 fed cage 4.</td></tr>
<tr><td></td><td></td><td></td><td>Sept. 14</td><td>Case 4 fed cages 1, 2, and 3, condensed.
Case 3 fed cage 4.</td><td>Case 4 fed cage 2.
Case 3 fed cages 1 and 2.</td></tr>
<tr><td></td><td></td><td></td><td>Sept. 15</td><td>Case 3 fed cage 4.</td><td>Case 3 fed cages 1 and 2.
Case 4 fed cages 3 and 4.</td></tr>
<tr><td></td><td></td><td></td><td>Sept. 16</td><td>On Sept. 16 there remained in the 4 cages only 27 surviving <i>Culex fatigans</i>. These were kept thereafter at 26° C. and fed on sirup. On dissection from time to time 20, or 74 per cent, showed larval forms of filariæ. (See Table No. 1.)</td><td>On Sept. 16 there remained in the 4 cages 160 surviving <i>Ædes calopus</i>, which were kept thereafter at 26° C. and fed on sirup; 124 of these were dissected from time to time, but none were found infected with developmental forms of filariæ.</td></tr>
<tr><td></td><td></td><td></td><td>Sept. 16</td><td colspan="2">Column 3.
400 <i>Culex fatigans</i> were caught in Charleston at "The Old Folks' Home" on the walls of rooms occupied by nonfilarial patients and placed, 100 in each of 4 cages unsupplied with food other than blood of filarial patients, who introduced their hands into the cages as indicated below. After each feeding, the engorged mosquitoes were removed and placed in a common cage supplied with simple sirup.</td></tr>
<tr><td></td><td></td><td></td><td>Sept. 16</td><td colspan="2">Case 4 fed 11 mosquitoes.</td></tr>
<tr><td></td><td></td><td></td><td>Sept. 17</td><td colspan="2">Case 2 fed 13 mosquitoes.</td></tr>
<tr><td></td><td></td><td></td><td>Sept. 18</td><td colspan="2">Case 2 fed 7 mosquitoes.</td></tr>
<tr><td></td><td></td><td></td><td>Sept. 19</td><td colspan="2">Cases 2 and 3 fed 10 mosquitoes.</td></tr>
<tr><td></td><td></td><td></td><td>Sept. 20</td><td colspan="2">Case 4 fed 3 mosquitoes.</td></tr>
<tr><td></td><td></td><td></td><td>Sept. 21</td><td colspan="2">Case 3 fed 8 mosquitoes.</td></tr>
<tr><td></td><td></td><td></td><td></td><td colspan="2">Total......52 engorged mosquitoes.
These 52 <i>Culex fatigans</i> which fed on filarial patients were dissected from time to time; 65 per cent proved to be infected with filariae. (See Table No. 2.)</td></tr>
</table>

DIFFERENT BITING HABITS OF CULEX FATIGANS AND ÆDES CALOPUS.

In attempting to infect *Culex fatigans* and *Ædes calopus* with filariæ, they were confined to small cages about 1 foot square, into which filarial patients introduced their hands through gauze sleeves between 11 p. m. and 1 a. m. For the period of a week no food was supplied other than the opportunity to bite filarial patients every night or every other night. (See Table No. 5.)

The two species manifested very different biting habits under the conditions imposed by the experiment. In the presence of electric light *Culex fatigans* would not bite at all, and bit very poorly even after exclusion of light from their cage by a piece of thick black cloth in which the cage was wrapped. *Ædes calopus*, however, under the same conditions, attacked the hands of the patient immediately and filled with blood irrespective of light or darkness.

The reduction in numbers from 400 *Culex fatigans* to 27 in a week's time, when life depended upon blood-sucking at midnight in a small cage, indicates the almost absolute aversion which this species has to biting when confined to a small cage. There was no such reduction in numbers of *Ædes calopus*, since 160 of the original 400 survived at the end of the week; all except 43 of the 400 *Ædes calopus* filled with blood the first night.

III. PREVENTION OF SPREAD OF FILARIASIS.

Filariasis is entirely preventable, due to the fact of its transmission to man solely through the bites of mosquitoes which have become infected by biting infected individuals. Prevention of the spread of filariasis could be brought about in a community either by ridding the human host of microfilariæ through the use of some drug in the way that cinchonization aims to eradicate malaria from the circulation, or by ridding the community of the mosquito host of the filaria. Inasmuch as no means is known of reducing the number of microfilariæ in the blood, preventive measures are necessarily dependent upon mosquito eradication; this in the case of *Culex fatigans* is a comparatively easy undertaking, because *Culex fatigans* is a domestic mosquito, breeding in fresh water in back yards, in cisterns, rain barrels, tin cans, and other miscellaneous unnecessary artificial containers of rain water on the premises.

A compelling municipal ordinance or concerted action by every property owner directed to the abolishment of all collectors of water on the premises would practically rid the community of the *Culex fatigans* mosquito. If the municipality imposes upon the citizen the obligation to destroy all collectors of water on his premises, the municipality thereby obligates itself to furnish the citizen with the necessary means of getting good water; this the city can best do through the agency of a city-owned water system. A municipal water supply piped to every street, alley, and home in the town, coupled with a compelling municipal ordinance requiring the use of the city water exclusively and requiring the destruction of all collectors of rain water, will rid a community of filariasis by reducing the number of *Culex fatigans* to a negligible plane.

IV. ANATOMY OF THE PROBOSCIS IN RELATION TO FILARIA TRANSMISSION.

In order to understand the function of the proboscis in transmitting larval filariæ to man, one must know something of the anatomy of the proboscis and the mechanism of its action.

A casual glance at a mosquito's proboscis at rest gives one the impression of a simple scale-covered tube projecting from the mosquito's head (Pl. I, fig. 1); but if the mosquito is observed in the act of biting, the proboscis is very plainly seen to resolve itself into two parts, namely, an inclosed stilette bundle and an inclosing sheath. (Pl. I, figs. 2 and 3.)

If one will watch a mosquito undisturbed in the act of biting upon the back of his hand he will see with the naked eye that the proboscis resolves itself into an inclosed slender rigid piercing stilette bundle which penetrates the skin and acts as the conveyor of blood to the mosquito and an inclosing stout flexible sheath, slit along its dorsal border to enable it to bend or elbow away from the stilette bundle, leaving the latter free and unsheathed except where the distal end of the sheath surrounds the stilette bundle.

We have then to consider the anatomy of the stilette bundle and the anatomy of the proboscis sheath.

The stilette bundle is constructed for piercing the skin and for blood sucking and is made up of a labrum, two mandibles, two maxillæ and a hypopharynx. (Pl. II, figs. 1, 2, and 3.) The labrum is a long narrow grooved stiff spine ending in a penlike point; the mandibles and maxillæ are slender lancets apparently serrated at the ends; the hypopharynx is a flat plate carrying a small central canal throughout its length, which is continuous with the common salivary duct down which pass the malarial and yellow fever infection. The six parts of the stilette bundle are held together anatomically only at their proximal ends where they arise from the mosquito's head; throughout their length they are separate from each other except that they lie in apposition. The apposition of the flat hypopharynx to the groove of the labrum converts that groove into a canal and it is up this canal that blood passes to the mosquito's mouth by force of suction. When the mosquito bites, the entire stilette bundle is forced into the wound.

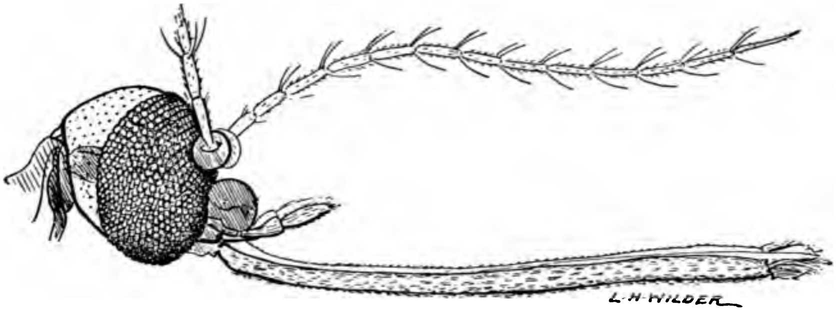

Fig. 1.—Proboscis of mosquito, grooved on its dorsal border and with the stilette bundle resting in the groove.

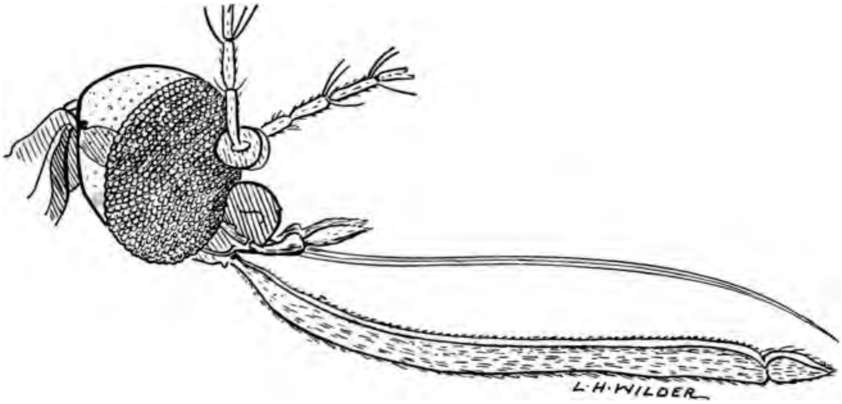

Fig. 2.—Same, but with stilette bundle entirely free.

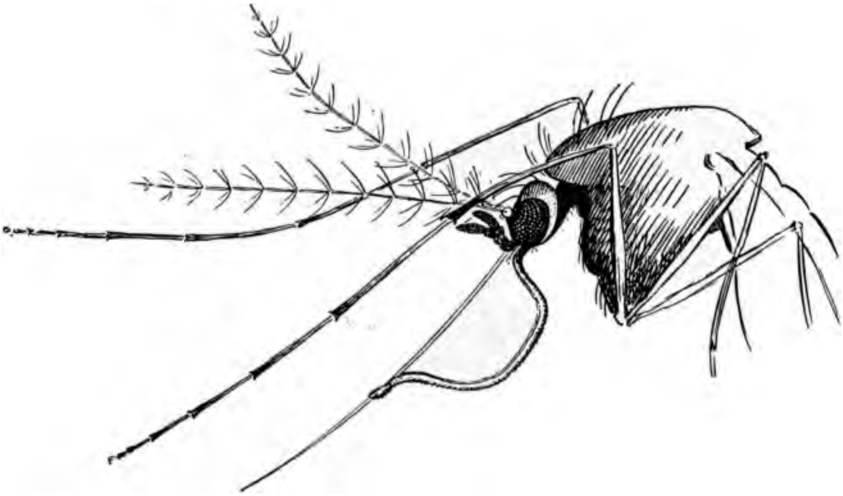

Fig. 3.—Mosquito in the act of blood-sucking, the stilette bundle being free from the sheath except at the distal end of the sheath. After Bahr.

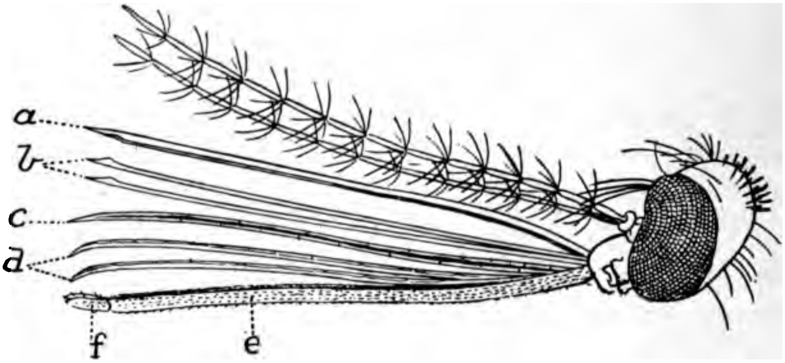

Fig. 1.—Proboscis (after Daniels) resolved into stilette bundle (a, labrum; b, two mandibles; c, hypopharynx; d, two maxillae); and sheath (e, labium).

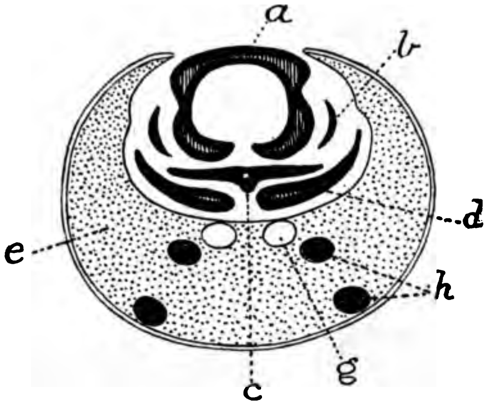

Fig. 2.—Transverse section of proboscis, after C. W. Daniels, laboratory studies in tropical medicine. Stilette bundle (a, labrum; b, two mandibles; c hypopharynx; d, two maxillae); Sheath (e, containing g, tracheae; h, muscles).

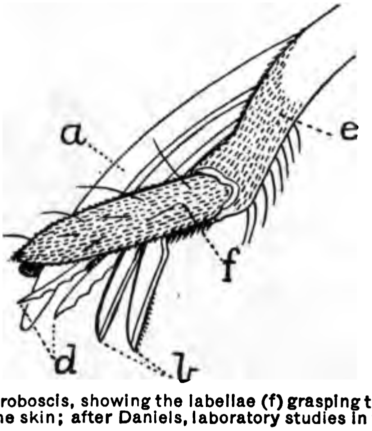

Fig. 3.—Anterior end of proboscis, showing the labellae (f) grasping the stilette bundle as in the act of piercing the skin; after Daniels, laboratory studies in tropical medicine.

The sheath is termed the labium. It is a cylindrical, stout, chitinous organ, covered with scales, and bearing a deep groove on its dorsal border in which lies the stilette bundle but from which the stilette bundle escapes in the act of blood sucking. It is composed of connective tissue in which lie a pair of tracheæ and also muscles and nerves. Its proximal end communicates with the head and its distal end terminates in two articulating lobes (labellæ) which during the biting act separate from each other and are applied to the surface of the skin and probably serve to grasp the stilette bundle and help to support the stylets as they sink between the two labellæ deeper and deeper into the skin while the labium is being bent down out of the way into a loop.

THE TWO COURSES OF FILARIÆ THROUGH THE PROBOSCIS.

The inward course and the outward course of filariæ through the proboscis are very different. Their inward course is by way of the stilette bundle which is intimately associated with blood sucking, but their outward course is by way of the proboscis sheath or labium which has no relation to blood sucking. Necessarily the inward course of microfiliariæ is with the ingested blood which is through the canal formed by the apposition of the hypopharynx to the groove of the labrum and thence to the mosquito's stomach. The microfilariæ after penetrating the stomach wall and undergoing metamorphosis in the thoracic muscles migrate as larvæ through the connective tissue spaces of the mosquito, first through its neck, then through its head and finally into the connective tissue spaces of the labium. The labium is a closed structure; it has no openings through which the larvæ can escape from their mosquito host.

If an infected mosquito is observed under the microscope, the filiariæ can be watched moving about in the connective tissue spaces of the labium awaiting an opportunity to get back into man at the time of the next blood sucking.

When the time of the infecting bite arrives, the stilette bundle penetrates the skin and plugs the opening; the labium bends or elbows away from the stilette bundle except where the labellæ grasp it; the filariæ escape from the inner thin surface of the labellæ by penetrating the intact thin Dutton's membrane; they fall on the skin close to the wound which the stilette bundle fills; they then penetrate the normal skin and pass to the lymphatics and lymph glands, but do not enter the blood stream through the mosquito puncture.

Under the headings "Filariasis defined," "The life cycle of *Filaria bancrofti*," "The anatomy of the mosquito's proboscis," and "The two courses of filariæ through the proboscis," no claim for originality is intended. Credit for the various discoveries which go to complete our knowledge on these subjects belongs to various authors and will be found on reference to the following publications:

Annett, Dutton & Elliott; Report on the malaria expedition to Nigeria. Pt. 2, Filariasis. Mem. 4 of the Liverpool School of Tropical Medicine. 1901.

Bahr: Filariasis and elephantiasis in Fiji. London, 1912.

Daniels: Studies in laboratory work. London, 1903.

Fülleborn: Die Filarien des Menschen. Handb. d. pathogenen Mikroorganismen, v. 8, 1913, pp. 185–344, figs. 1–41, pls. 1–6. (2. vermehrte Aufl.)

Giles: A handbook of the gnats or mosquitoes, giving the anatomy and life history of the Culicidae. 2. ed. London, 1902.

Lebredo: Metamorphosis of Filaria in the body of the mosquito (*Culex pipiens*). J. Infect. Dis., Suppl. 1, 1905, p. 332.

Low: A recent observation on *Filaria nocturna* in Culex, probable mode of infection of man. Brit. Med. J., 1900, v. 1, p. 1456–57.

Manson: Tropical diseases, a manual of the diseases of warm climates. 5. ed. London, 1914.

Theobald: Monograph of the Culicidæ of the world. v. 4, 3. London, 1907.

HYGIENIC LABORATORY BULLETINS OF THE PUBLIC HEALTH SERVICE.

The Hygienic Laboratory was established in New York, at the Marine Hospital on Staten Island, August, 1887. It was transferred to Washington, with quarters in the Butler Building, June 11, 1891, and a new laboratory building, located in Washington, was authorized by act of Congress March 3, 1901.

Of the bulletins published by the laboratory since its establishment, copies of the following are available for distribution and may be obtained without cost by applying to the Surgeon General, United States Public Health Service, Washington, D. C.

No. 2.—Formalin disinfection of baggage without apparatus. By M. J. Rosenau.

No. 43.—The standardization of tetanus antitoxin (an American unit established under authority of the act of July 1, 1902). By M. J. Rosenau and John F. Anderson.

No. 46.—*Hepatozoon perniciosum* (n. g., n. sp.); a hæmogregarine pathogenic for white rats; with a description of the sexual cycle in the intermediate host, a mite (*lelaps echidnimus*). By W. W. Miller.

No. 50.—Further studies upon the phenomenon of anaphylaxis. By M. J. Rosenau and John F. Anderson.

No. 51.—Chemical tests for blood. By Joseph H. Kastle.

No. 52.—Report No. 3 on the origin and prevalence of typhoid fever in the District of Columbia (1908). By M. J. Rosenau, Leslie L. Lumsden, and Joseph H. Kastle.

No. 53.—The influence of certain drugs upon the toxicity of acetanilide and antipyrine. By Worth Hale.

No. 55.—Quantitative pharmacological studies; adrenalin and adrenalin-like bodies. By W. H. Schultz.

No. 59.—The oxidases and other oxygen catalysts concerned in biological oxidations. By Joseph Hoeing Kastle.

No. 61.—Quantitative pharmacological studies; Relative physiological activity of some commercial solutions of epinephrin. By W. H. Schultz.

No. 65. Facts and problems of rabies. By A. M. Stimson.

No. 73.—The effect of a number of derivatives of choline and analogous compounds on the blood pressure. By Reid Hunt and R. de M. Taveau.

No. 75.—Digest of comments on the Pharmacopœia of the United States of America (eighth decennial revision) and the National Formulary (third edition) for the calendar year ending December 31, 190[illegible] [illegible] Murray Galt Motter and Martin I. Wilbert.

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PLATE III.

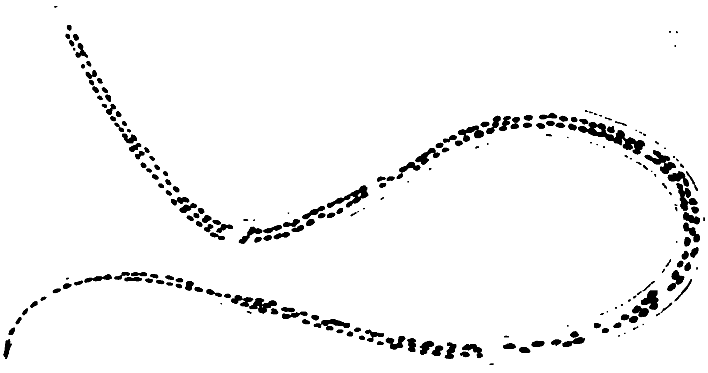
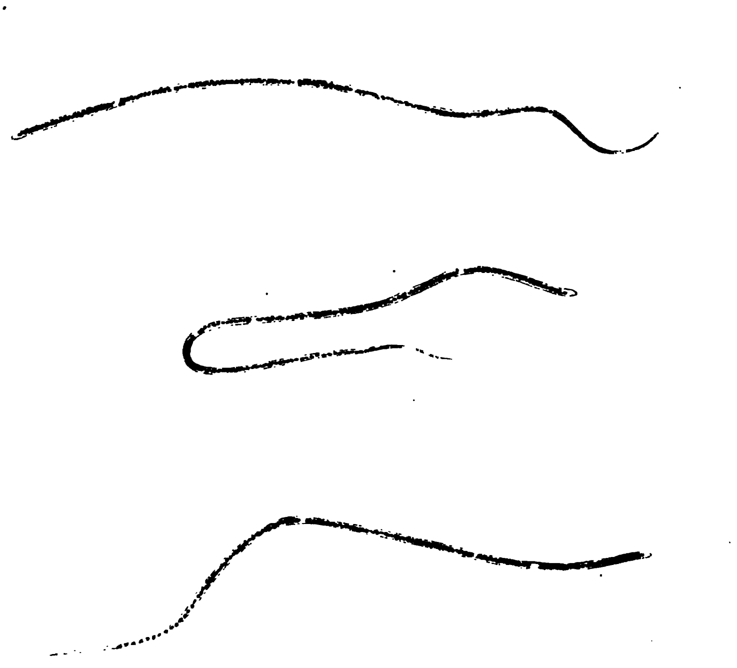


FIG. 1. *Microfilaria bancrofti* with sheath, from blood taken at Charleston, S. C. Stained with hematoxylin.



L. H. WILDER

FIG. 2. Filariæ (without sheath) in thoracic muscles of *Culex fatigans*, 9 hours after ingestion of filarial blood; infected at Charleston, S. C. Teased preparation.

PLATE IV

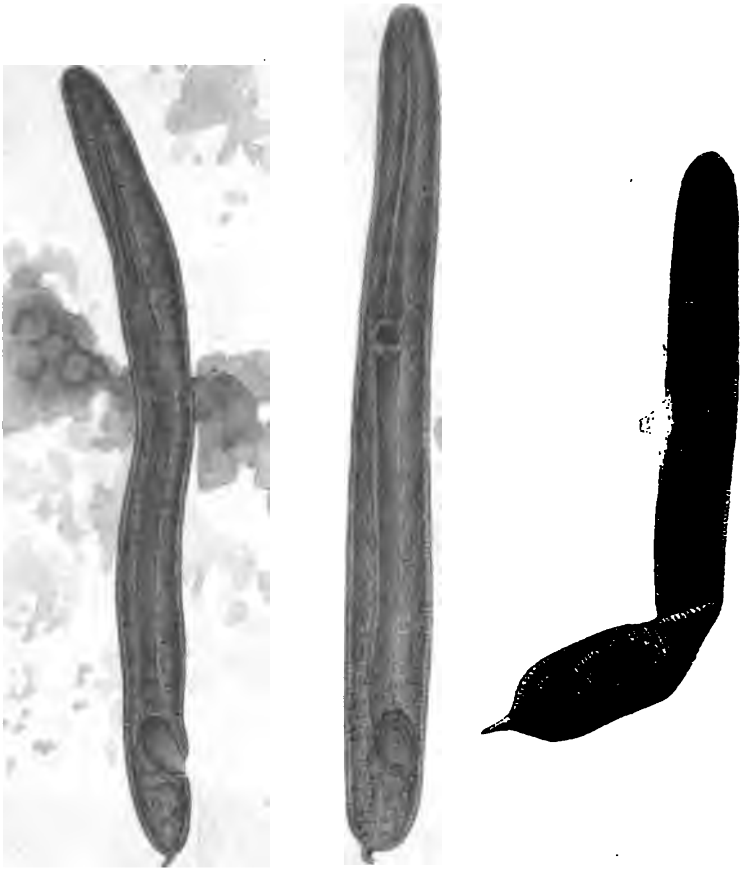


FIG. 1.

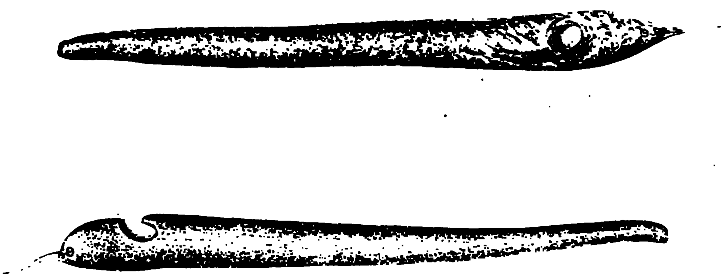


FIG. 2.

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FIGS. 1 and 2. Larvæ of *Filaria bancrofti* in thoracic muscles of *Culex fatigans* within 10 days after ingestion of blood; infected at Charleston. Teased preparations.

PLATE V.

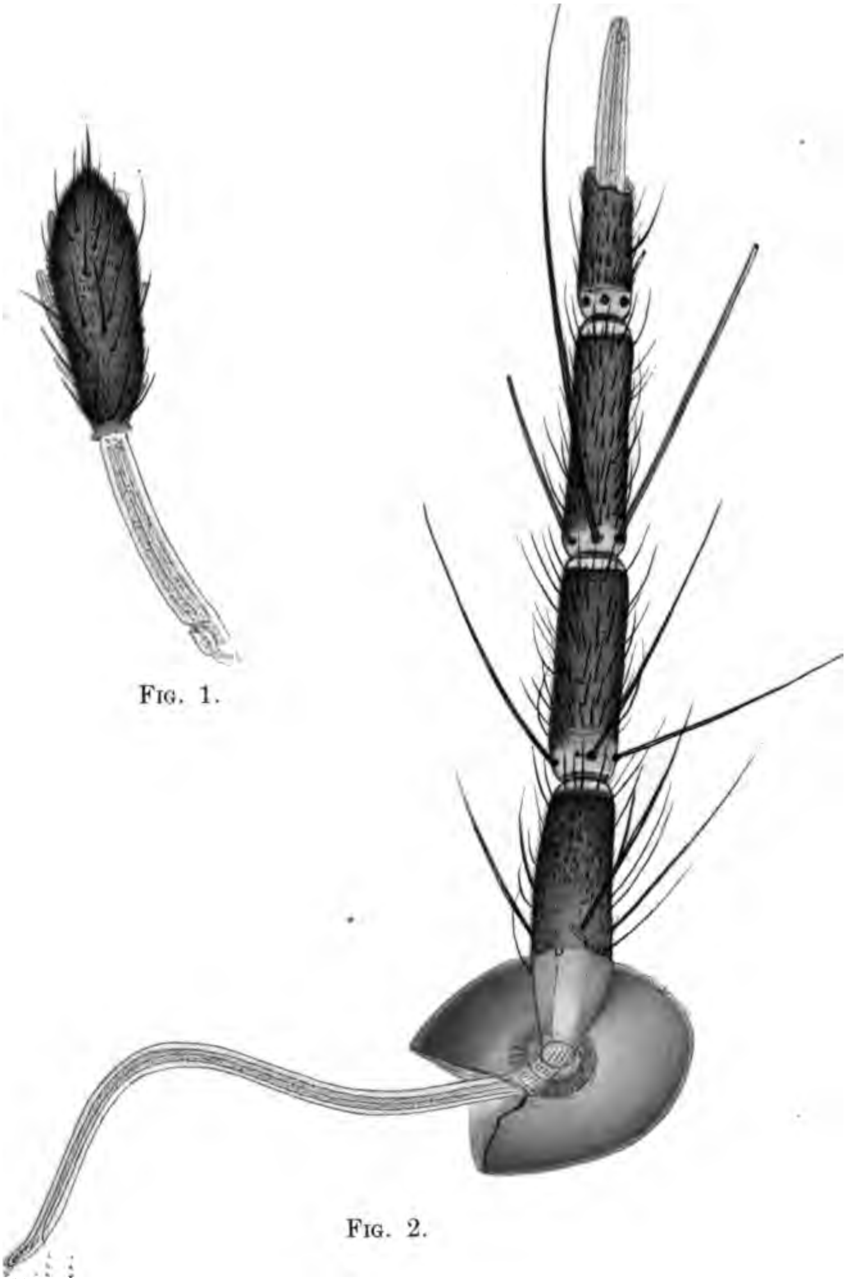

FIG. 1.

FIG. 2.

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FIG. 1. Larva headed into a palpus.

FIG. 2. Larva of *Filaria bancrofti* headed into an antenna of *Culex fatigans*. From mosquitoes infected at Charleston, S. C.

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PLATE VI.

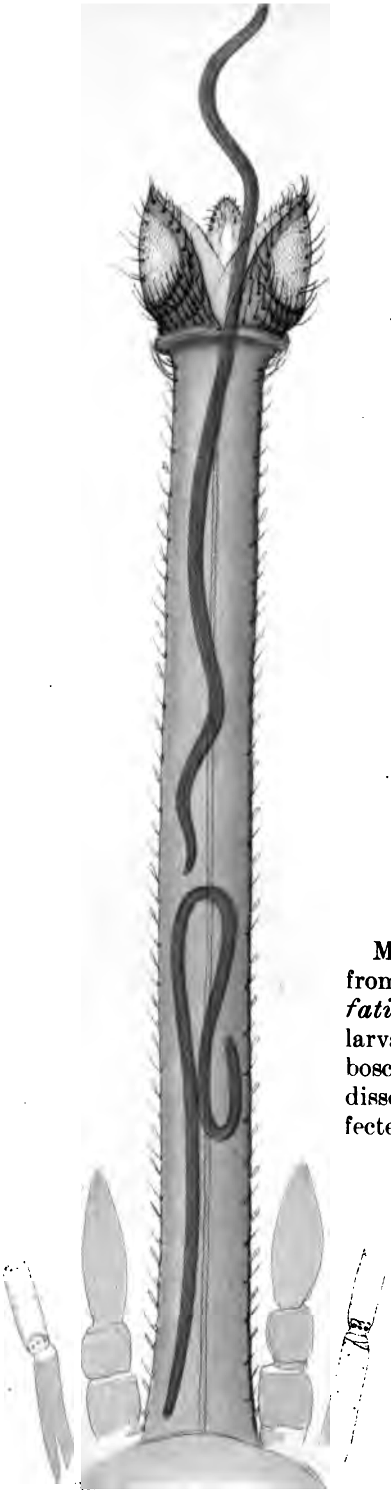

FIG. 1.

Mature larva escaping from proboscis of *Culex fatigans;* one mature larva coiled in base of proboscis. From mosquito dissected after being infected at Charleston, S. C.

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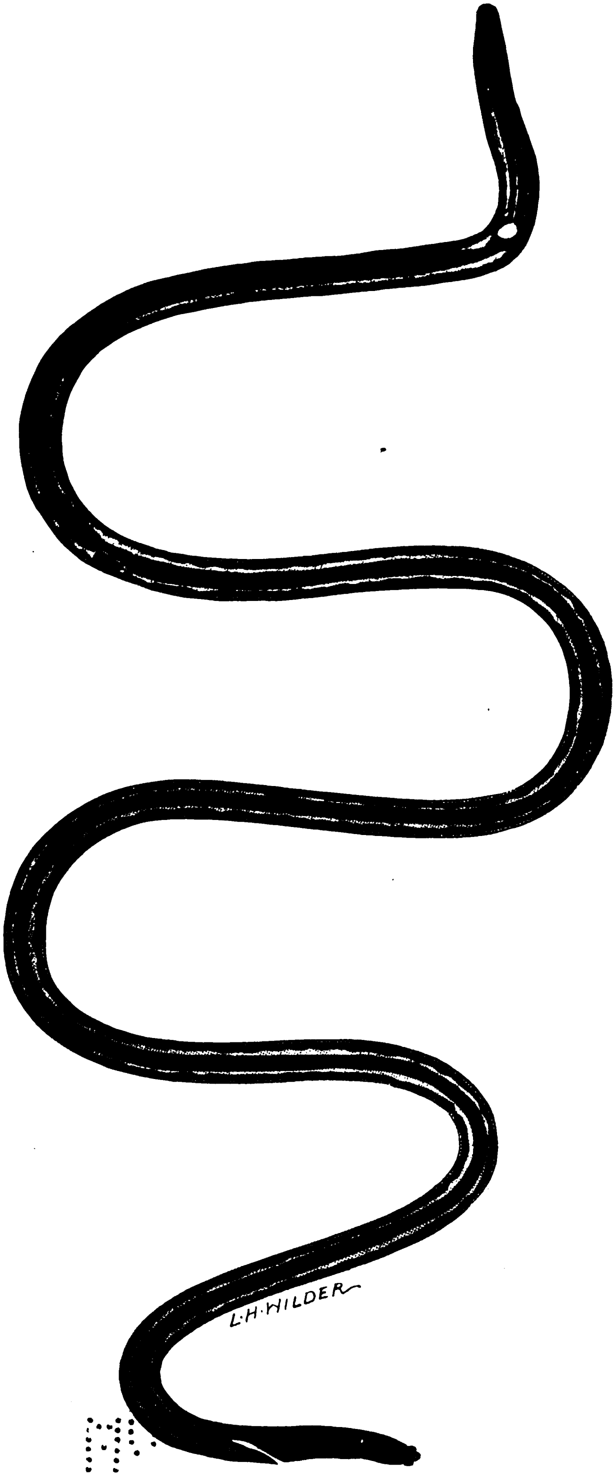
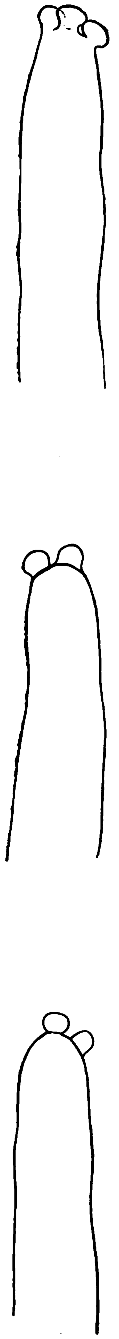


Fig. 1.—Larva of *Filaria bancrofti* at time of escape from proboscis of *Culex fatigans.*



Figs. 2, 3, and 4.—Showing two and three caudal papillae of larvae of *Filaria bancrofti* at time of escape from *Culex fatigans*. From preparations made on dissection of infected mosquitoes at Charleston, S. C.

PLATE VIII.

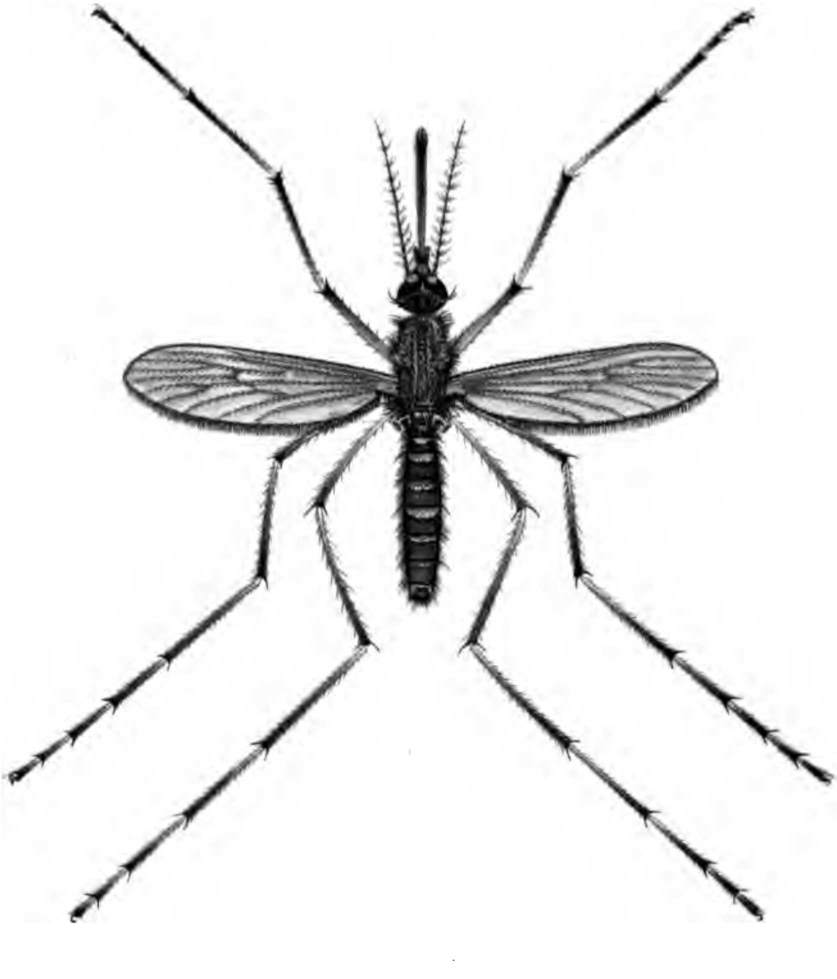


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Fig. 1. Adult female *Culex fatigans*.

PLATE IX.

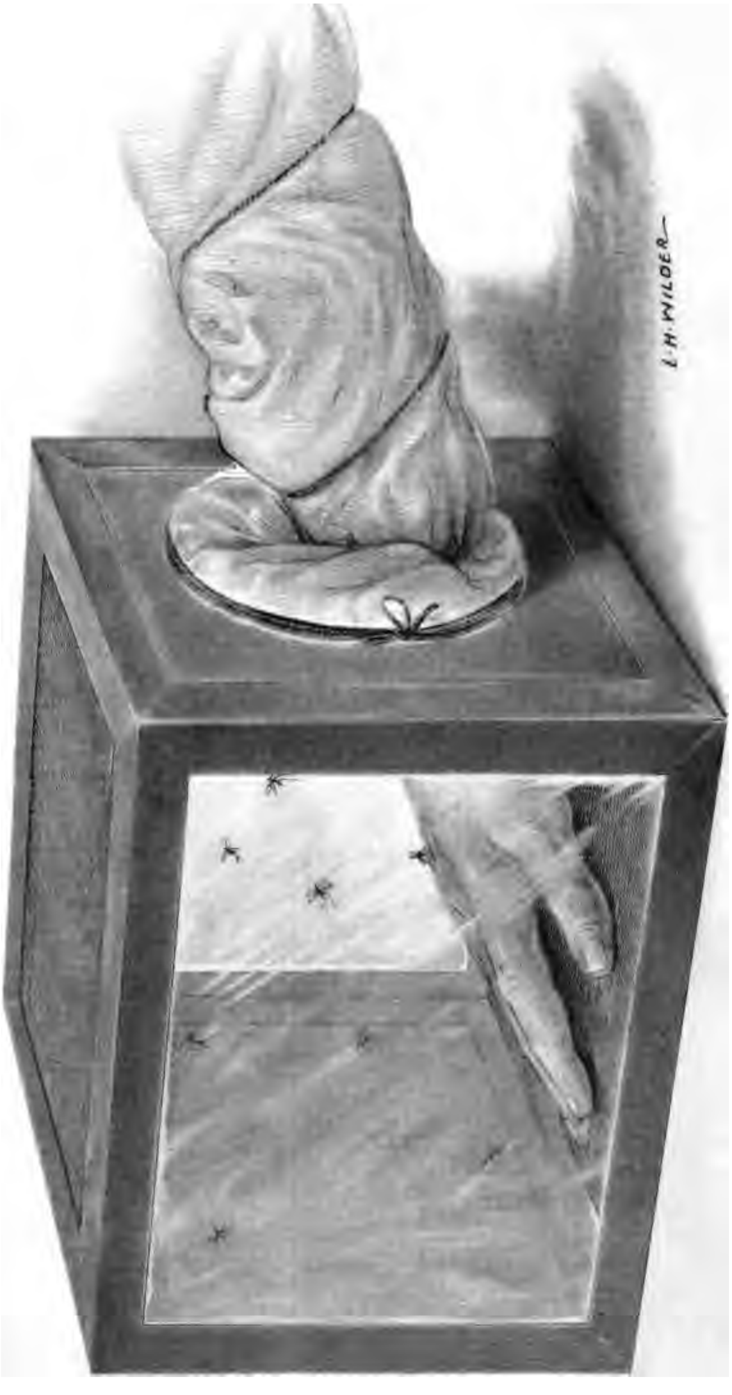

Fig. 1. Mosquito cage and sleeve.

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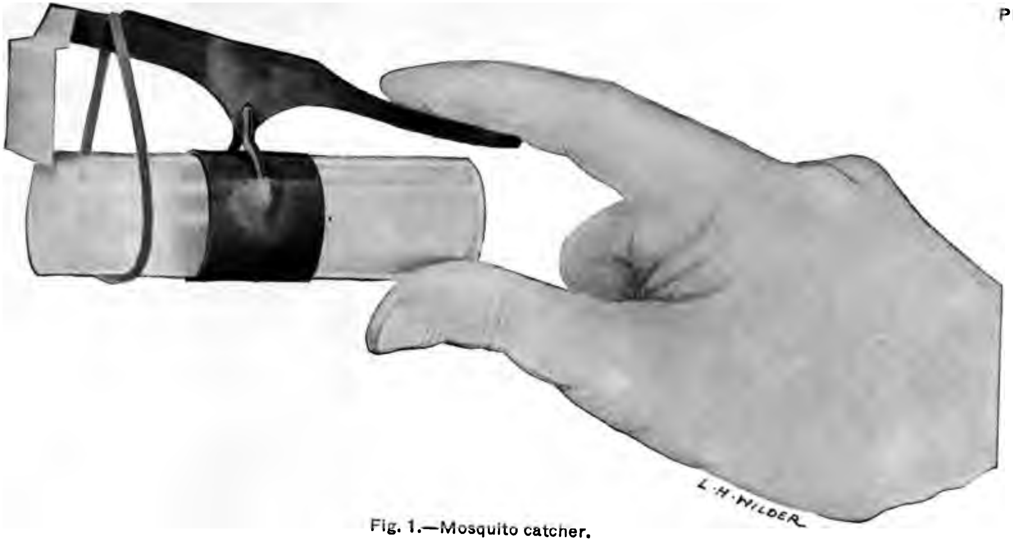

Fig. 1.—Mosquito catcher.

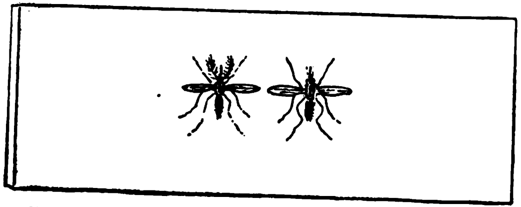

Fig. 2.—Method of mounting mosquitoes on glass slide with mucilage or Canada balsam.